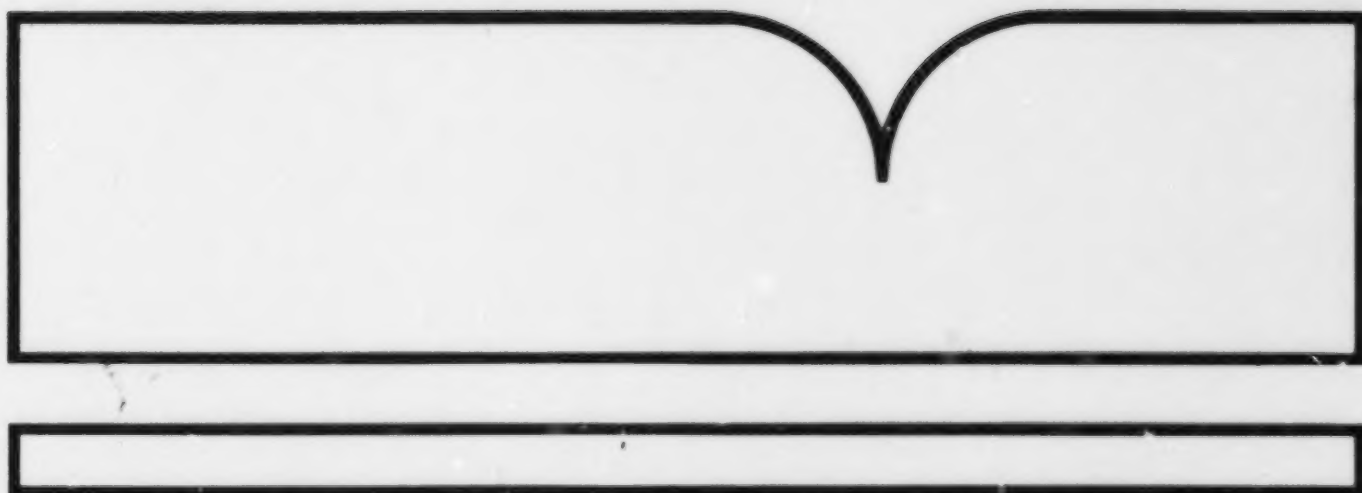


Urban Runoff Receiving Water Impacts
Program Overview

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URBAN RUNOFF RECEIVING WATER IMPACTS: PROGRAM OVERVIEW*

By Richard Field¹ and Robert Turkeltaub²

INTRODUCTION

Receiving water impacts are a major national concern. We are spending billions of dollars on secondary treatment plants, meanwhile urban stormwater and combined sewer overflow (CSO) are still uncontrolled. To attain the goals set forth in PL 92-500 and PL 95-217 in an economical and efficient manner, those analyzing, planning, and designing controls must have an understanding of the impact of pollutants on receiving waters.

Very little information of this kind can be found; therefore, several years ago the United States Environmental Protection Agency (USEPA) Storm and Combined Sewer (SCS) Program began a modest effort to fill this data void and to develop control methodologies based on receiving water impacts. The basic objective of this paper is to present an overview of the SCS Program's receiving water impacts subprogram.

BACKGROUND

Recognition of the significance of stormwater-induced water pollution has been slow. Current interest is largely attributable to the efforts of the USEPA Storm and Combined Sewer Research, Development, and Demonstration Program.

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Springfield were evaluated using the CSPSS (12). The simulation of James River DO concentrations was calibrated to continuous in-stream DO measurements collected by the USGS between 1974 and 1977. This calibrated CSPSS model was then used to simulate the impact of the recently completed AWT facility in Springfield and to quantify the impact of urban stormwater runoff control alternatives.

Since 1954, six major fishkills have occurred on the James River after storm events. The receiving water analysis conducted using the CSPSS indicates that urban stormwater pollution was probably not the major cause of these fishkills. Rather, it appears that the poor quality secondary effluent of the WWTP caused the fishkills. The observed low DO concentrations on the James River were apparently due to a combination of factors, which may include the resuspension of dry-weather benthic deposits, poor quality secondary effluent, and infiltration/inflow into the Springfield collection system.

ACKNOWLEDGMENTS

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Only within the past 20 yr, has it been recognized that waters discharged from separate storm sewers contain pollutants. Rain falling on an urban area picks up pollutants from the air, dusty roofs, littered and dirty streets and sidewalks, traffic byproducts (gasoline and oil drippings, tire residuals, brake ware, vehicular exhaust), metallic corrosion, hazardous spill materials and chemicals applied for fertilization, control of ice, rodents, insects, and weeds.

Urban Runoff Characterization.—Fig. 1 shows representative strengths of wastewaters based on data from test areas in eleven urban locations (10). The average five-day biochemical oxygen demand (BOD_5) concentration in combined

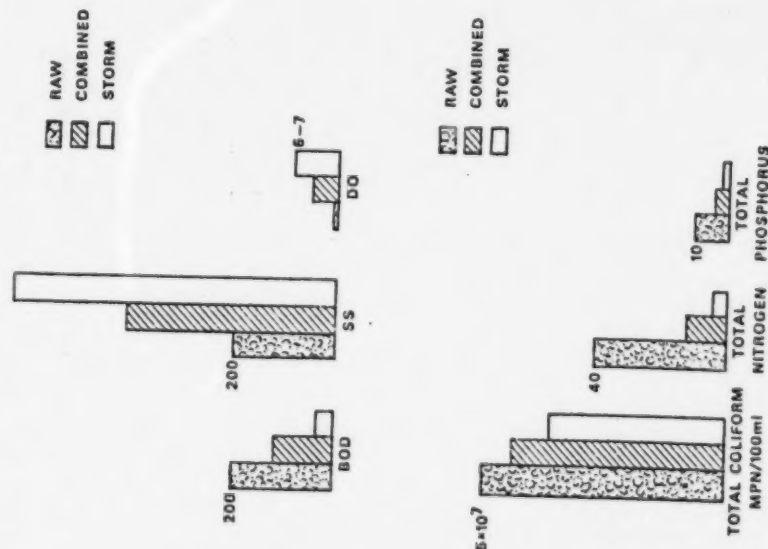


FIG. 1.—Representative Strength of Wastewaters: Flow-Weighted Means, in milligrams per liter

(domestic and storm) sewer overflow is approximately one-half the raw sanitary sewage BOD_5 . However, storm discharges must be considered in terms of their shockloading effect due to their great magnitude. A rainfall intensity of 1 in./h (2.5 cm/h) can produce flow rates up to 100 times dry-weather flow. Even separate stormwater is a significant source of pollution, having solids concentrations equal to or greater than untreated sanitary wastewater, and BOD_5 approximately equal to secondary effluent. Bacterial contamination of separate

stormwater is two to four orders of magnitude greater than concentrations considered safe for water contact.

Microbiological studies of storm runoff have shown consistent recoveries of pathogenic organisms (16), thus indicating that urban runoff may present a public health problem.

Representative Loads.—From 40%–80% of the total annual organic loading entering receiving waters from a city is caused by sources other than the treatment plant (3,20). During a single storm event, 95% of the organic load is attributed to wet-weather flow sources. The runoff of toxic pollutants, particularly heavy metals and petroleum hydrocarbons, is also high.

Potential Impacts.—Approximately one-half of the stream miles in this country are water quality limited and 30% of these stream lengths are polluted to a

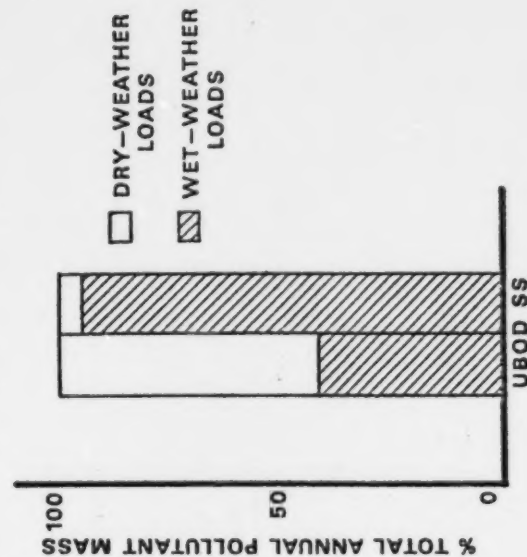


FIG. 2.—Total Wet-Weather and Dry-Weather Pollutant Load: Durham, North Carolina

certain degree with urban runoff (3). Thus, secondary treatment of dry-weather flow (DWF) is not sufficient to produce required receiving water quality, and control of runoff pollution becomes a requirement for maintaining stream standards at particular locations, e.g., Fig. 2 shows that if Durham, N.C. provided 100% treatment of municipal wastewater, the total annual reduction of ultimate BOD and suspended solids would only be 59% and 5%, respectively. Durham has a separate system. Combined systems, which are generally found in older more densely populated cities, offer a greater pollutional impact, since additional loads come from domestic wastewaters, dry-weather sediment washout, and more impervious and populated lands.

Now that urban runoff has been identified as a significant pollutant source the emphasis has been shifted from direct analysis of urban runoff to substantiating its impacts on receiving waters and developing source control methodologies

based on these impacts. Identified and quantified impacts and their associated impairment of designated beneficial uses of receiving waters are fundamental factors providing justification for funding stormwater and CSO countermeasure campaigns and passing abatement legislation.

For instance, in order for a CSO control project to qualify for Federal funding, a careful review must have shown that out of all the alternatives considered, the selected alternative is cost effective and required to protect the beneficial use of the receiving water, even after industrial effluent limitations and secondary treatment for dry-weather flows are achieved (9).

Ties between receiving water quality and stormwater discharges must be clearly established and delineated. Quantification of the impairment of beneficial uses and water quality objectives by such discharges is a major goal. Results from earlier SCS Program projects and limited results from others are now available.

RECEIVING WATER QUALITY IMPACTS

Data on the environmental impact of urban runoff are being gathered as a first step in developing methodology to quantify pollutant stress and evaluate the impact in relation to receiving water standards and desired uses.

Dissolved Oxygen Depletion.—The classical problem related to organic pollution of receiving waters is the consumption of instream oxygen by the bacterial breakdown of organic material. The resulting low levels of oxygen will destroy sensitive species of fish and aquatic organisms and may cause anaerobic conditions which produce objectionable end products. Accordingly, the SCS Program's first attempt at evaluating receiving water impacts was a project by the Sutron Corporation (6) wherein data from existing rain gages as well as flow and water quality monitors in and downstream of urban areas were assessed in an attempt to correlate dissolved oxygen (DO) depletion with urban runoff.

Although sites with specific instances of standards violations were located, no conclusions could be drawn on a national basis. Several other correlation attempts in Ohio and Indiana streams also proved fruitless (7,18).

Except for one occurrence in the Chattahoochee River after a July thunderstorm when the DO reached a low of 1.5 mg/l, the Chattahoochee project (11) also failed to show adverse DO impacts despite BOD₅ and other pollutant concentrations in the CSO ranging from 1-10 times that in the receiving streams.

The 1.5 mg/l DO level recorded in the Chattahoochee River is an indication of the potential negative impacts from oxygen demanding materials in urban storm runoff. At this point, although the SCS Program has not had complete success in ascertaining DO impacts from urban runoff, the Program should not attempt to write off DO demand as being a wet-weather related impact. Based on annual mass balance determinations, urban wet-weather organic loads are the same order of magnitude as dry-weather loads as indicated by Table 1, and 10 times greater during storm periods (2,5). However, a large fraction of the oxygen consuming material is associated with settleable and separable solids which in storm flow are usually larger (smaller surface to volume relationship and bacteria predominate on the surface layer) and in a more nonbiodegradable state than in sanitary effluent; therefore, the deoxygenation rate tends to be lower and time delayed. The fate of this material is related more to the hydrodynamics of the specific receiving water and to the specific wet-weather

oxygen transfer rates rather than to the advective transport and lumped and conventional rate assumptions used in traditional DO analysis.

Part of the problem in ascertaining DO impacts lies in locating urban areas free from all interferences except urban runoff. As Fig. 3 indicates, part lies in trying to derive data for unsteady state flow regimes caused by storms from sites set up for conventional dry-weather monitoring. Also, storm related changes in the deoxygenation rate, stream velocity, and reoxygenation rate are variables which can cause the DO sag to occur at remote locations as compared to relatively steady state dry-weather conditions. Another factor is the lack of money. Receiving water studies are expensive and the SCS Program and others can ill afford to spend substantial sums from their limited budgets on one project.

TABLE 1.—National Annual Urban Wet- and Dry-Weather Flow BOD₅ and COD Load Comparisons*

TYPE	PERCENT OF DEVELOPED AREA	ANNUAL DWF**			ANNUAL WWF**			PERCENT WWF	
		BOD ₅ MIL LB.	COD MIL LB.	BOD ₅ MIL LB.	BOD ₅ MIL LB.	COD MIL LB.	BOD ₅ MIL LB.	BOD ₅	COD
COMBINED	14.3	340	910	880	2640	72	74		
STORM	38.3	710	1890	440	2500	36	57		
UNSEWERED	47.4	310	830	360	2250	54	73		
TOTALS	100	1330	3630	1640	7390	55	67		
*ASSUMING									
		BOD ₅ (MG/L)	COD (MG/L)						
CSO		100	300						
URBAN STORMWATER		20	125						
DRY-WEATHER		30	80						

**LB = 0.454 KG

In Milwaukee, these problems were somewhat overcome (13). The city was desirous of providing the necessary receiving water impact analyses for evaluating CSO pollution and control and the SCS Program was able to interface with their 201, step 1 construction grant.

River sampling results provided strong evidence that CSO impacts intensified the DO sag. It was found that resuspension of the sediments caused rapid DO sags in the Milwaukee River after CSO events. Combined sewer overflows were found to contribute 40%-50% of the annual BOD loading to the sediments and the sediment oxygen demand (SOD) of the disturbed sediments was 100 times greater than SOD rates in situ (10 g O₂/m²/day versus 1,000 g O₂/m²/day). Fig. 4 shows the marked effect the disturbed sediment has on the DO in the river. The I-beams represent the range of the observed real river data and offer verification of model predictions using disturbed SOD rates.

Based on results identifying sediment as a major problem, the SCS Program undertook a project to track the fate of settleable materials discharged to flowing

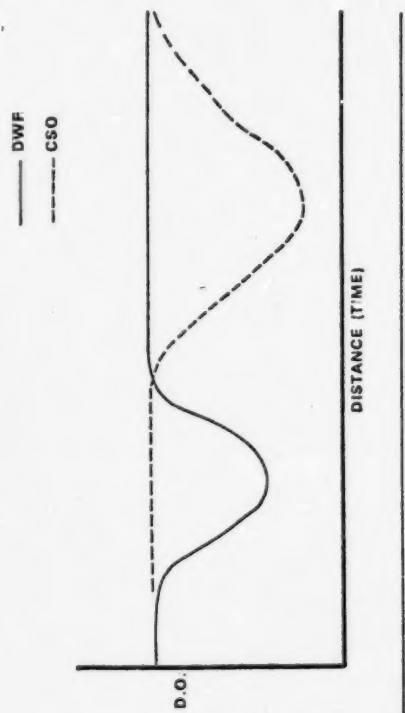


FIG. 3.—Comparative Locations of DO Sag and Water Quality Monitors

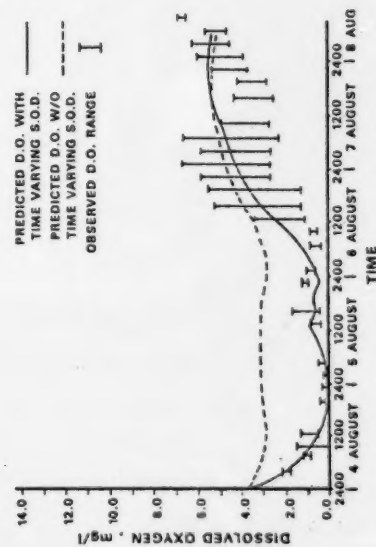


FIG. 4.—DO Storm Profile: Milwaukee River, Milwaukee Wisconsin

streams (8). The project clearly showed limitations with the current state-of-the-art of transport modeling.

Conventional receiving water quality models exclude sediment transport (and particulate flowfields) while existing sediment transport models only consider discrete sediments and not biochemical reactions. Furthermore, the present data base is inadequate to validate these sediment transport models. For them to be useful in wet-weather discharge analysis, it will be necessary to interface the sediment routines with the runoff routines and to build-in the appropriate

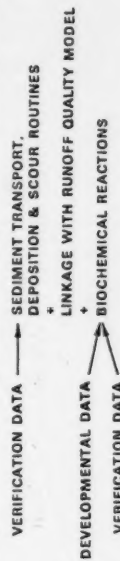


FIG. 5.—Receiving Water Sediment/Pollutant Impact Analysis

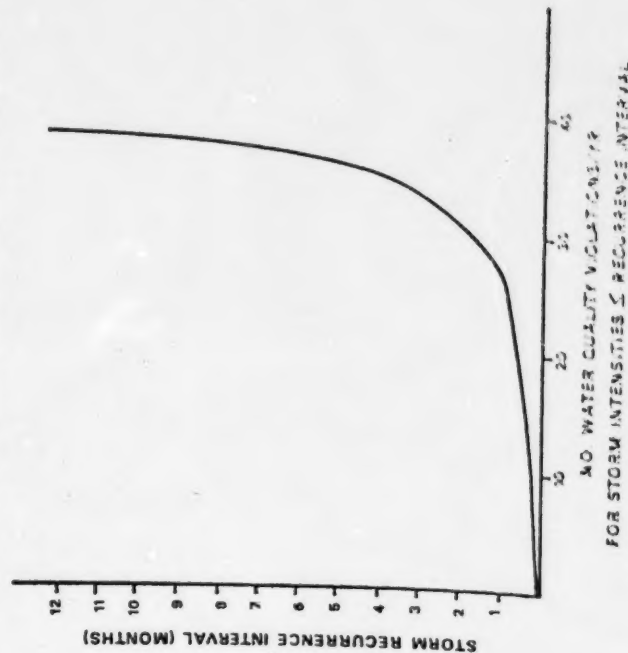


FIG. 6.—Water Quality (Fecal Coliform) Violations Versus Storm Recurrence Interval: Lake Onondaga, Syracuse, New York

biochemical reactions as indicated in Fig. 5. The question comes down to the level of effort required and the cost of developing a more complex model and data base.

Pathogen Concentrations.—Excess concentrations of bacterial indicator organisms in urban runoff will hinder water supply use, recreational use, and fishing/shell fishing use of the receiving water. A common bacterial standard for recreational use of water is a total coliform concentration of less than 1,000

organisms/100 ml and a fecal coliform concentration of less than 200 organisms/100 ml. However, coliform are merely indicating organisms and not pathogens. Their use as an indicator of human enteric contamination in storm runoff waters is not valid because some coliform in this flow originates from soils and animal fecal matter. Therefore, the SCS Program supported the Johns Hopkins University study (16), the conclusion of which was that the frequency of occurrence of human pathogenic organisms in storm flow is related to cross contamination from sanitary sewage. All stormwaters were found to contain disease causing viruses and bacteria because none of these waters are totally separated from sanitary waste sources. Pathogens were even found in the background waters used for control observations.

The aforementioned Milwaukee project (13) found that CSO is the major source of fecal coliform in the Milwaukee River and that removal of these overflows will nearly eliminate fecal coliform standards violations.

In a study conducted at Syracuse, N.Y. (14), the only water quality parameter which was significantly and adversely affected by CSO into Lake Onondaga was fecal coliform. As Fig. 6 shows, of the 65 annual CSO producing events, 38 resulted in discharges of a magnitude sufficient to cause violation of the bacterial standards in the contact recreational zone of the lake. A hypothetical 1 yr, 2 h storm would result in bacterial numbers in excess of the standard of 200 cells/100 ml in all "upper" segments of the lake, and a maximum concentration greater than 11,000 fecal coliform cells/100 ml in the northern basin where contact recreation is anticipated. A storm of this magnitude would cause violations of coliform standards for a period in excess of three days. However, it is probably not necessary to treat a 1-yr frequency storm. It can be seen from Fig. 6 that treatment provided for a 2-month frequency storm will eliminate 82% of the coliform violations. The cost of providing additional treatment for the larger storms at the so called knee of the curve is disproportionately large compared to the rapidly decreasing benefits achieved beyond this point on the curve. It should be emphasized that the concept of disproportionate returns is a decision-maker's tool and that the bottom line lies with the desired frequency of water usage which is a local prerogative.

At Lake Washington, human viruses were readily detected in CSOs (19). Based on literature indicating that viruses present at detectable levels can cause infection, CSO may be a health hazard to people using Lake Washington beaches soon after overflows.

Nutrients.—Surface water bodies with long detention times, such as lakes and estuaries, tend to concentrate nutrients, organics, and metals in both the supernatant and bottom muds. As a result of anaerobic conditions, boat mixing, currents (from tributary sources), and concentration changes, these pollutants can be resuspended and become available for plant growth or lead to a depletion of DO.

In Lake Eola, Fla., urban runoff was found to be the sole cause of lake degradation (Wanielista, M., et al., Unpublished Report, EPA Grant No. R-805580). Fig. 7 depicts the Lake Eola watershed. Urban runoff is the only flow entering the lake. Phosphorous concentrations in the runoff were found to significantly increase algal productivity. Table 2 indicates the lake's algal growth response to urban runoff. Based on the first phase recommendations of the SCS Program's project, the USEPA 314 Clean Lakes Program is funding

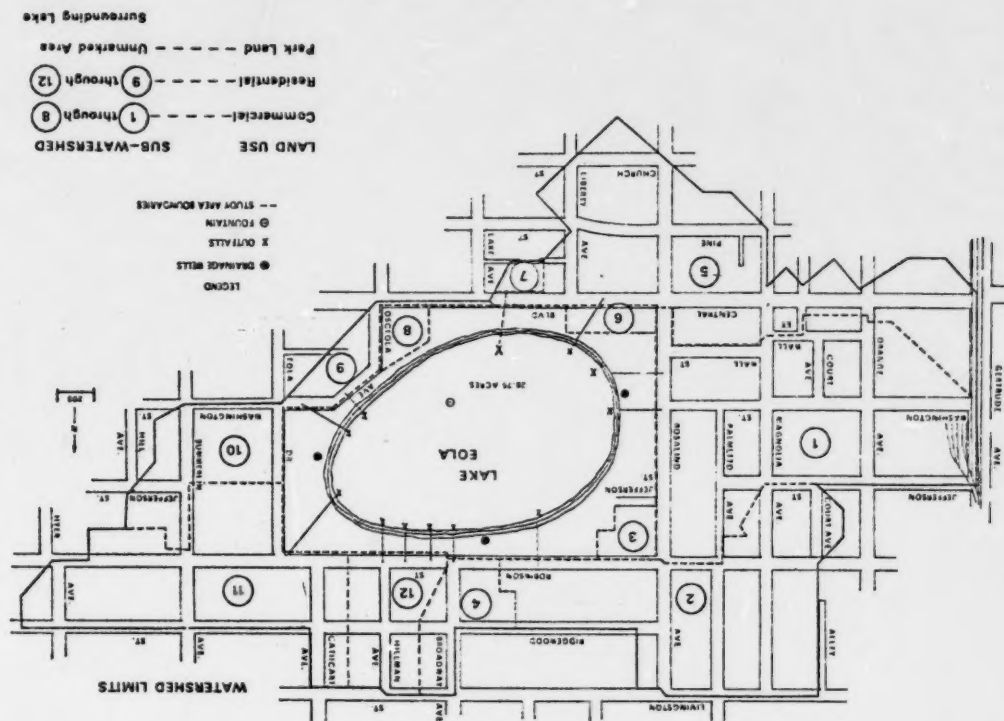


FIG. 7.—Lake Eola Watershed: Orlando, Florida

a phase two restoration program. It is intended to jointly fund a phase three post restoration evaluation.

Biological Investigations.—A full assessment of the environmental impact of urban stormwater runoff requires a comprehensive in-depth analysis of water quality and the biological community in the receiving stream. Not only the physical and chemical characteristics of the receiving water body and its sediment should be examined, but also the aquatic and benthic organisms.

TABLE 2.—Algal Response to Urban Runoff: Lake Eola, Orlando, Florida

Variable (1)	Average Chlorophyll-a Concentration, in milligrams per cubic meter					
	Initial (2)	4 days (3)	7 days (4)	8 days (5)	9 days (6)	14 days (7)
Control	11.7	12.1	6.5	7.1	5.0	1.3
Lake water + 5% runoff	11.5	25.2	26.7	30.6	28.5	17.7
Lake water + 10% runoff	11.7	38.9	38.4	43.3	38.6	31.5
Lake water + 25% runoff	11.7	64.5	74.2	91.6	84.7	68.6
Lake water + 50% runoff	11.7	33.9	41.8	44.2	44.2	15.8
Lake water + 75% runoff	11.7	22.4	16.6	20.7	16.8	7.1
Lake water + 100% runoff	11.7	23.3	16.2	14.5	15.3	3.7

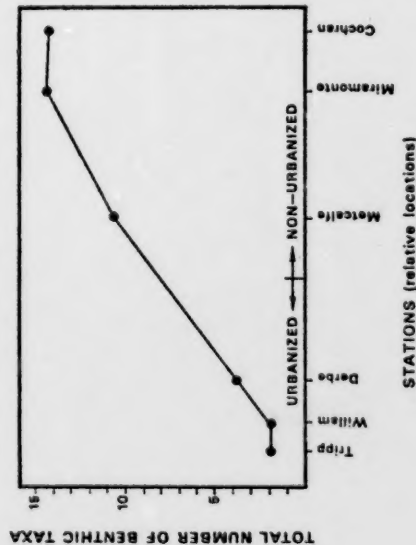


FIG. 8.—Abundance of Benthic Taxa: Coyote Creek, San Jose, California

Such an investigation is being conducted in San Jose, Calif. (17) where preliminary sampling showed that the nonurbanized section of Coyote Creek supported a diverse population of fish and benthic macroinvertebrates as compared to the urbanized portion which was completely dominated by pollution tolerant algae, mosquito fish, and tubificid worms. Fig. 8 shows this point. Similar results were found in the previously mentioned Lake Washington project (19) where bottom organisms (aquatic earthworms) near storm and combined sewer outfalls were more pollution tolerant relative to those at a distance from

these outfalls. Aquatic earthworm numbers and biomass were found to be enhanced within the zone of influence of the monitored combined sewer and storm drain outfalls in Lake Washington, e.g., at one combined sewer outfall the biomass enrichment amounted to 82% of the background control value and aquatic earthworms constituted 90% of the biomass.

Toxicity.—Toxicity problems can result from minute discharges of metals, pesticides, and persistent organics which may exhibit a subtle long-term effect on the environment by gradually accumulating in sensitive areas.

TABLE 3.—Metals Discharged to Harbor from New York City Sources (3)

Source (1)	Cu (2)	Cr (3)	Ni (4)	Zn (5)	Cd (6)
Plant effluents	1,410	780	930	2,520	95
Runoff*	1,990	690	650	6,920	110
Untreated wastewater	980	570	430	1,500	60
Total weight, in pounds per day	4,380	2,040	2,010	10,940	265
Weighted average concentration, in milligrams per liter	0.25	0.12	0.11	0.62	0.015

*In reality, shockload discharges are much greater.

TABLE 4.—Total Versus Particulate Mass from Combined Sewer and Storm Sewer Overflow Point: Lake Washington, Seattle, Washington

Variable (1)	Selected CSO Point		Selected Storm Drain Point	
	Total mass, in kilograms (2)	Particu- late mass, in kilograms (3)	Total mass, in kilograms (4)	Particu- late mass, in kilograms (5)
Suspended solids	3,920	3,920	2,238	2,238
Cu	1.33	1.04	1.16	0.745
Hg	0.026	0.023	not determined	not determined
Pb	1.46	1.01	6.04	5.32
Zn	3.20	2.20	2.74	1.76
Al	66.0	63.4	97.2	93.9
Organic C	458	193	299	168
Total P	45.1	12.8	8.73	4.60
Oils and greases	330	not applicable	113	not applicable
Chlorinated HC	not determined	0.460G	not determined	0.388G

Note: 1 kg = 2.2 lb.

The SCS program has been analyzing for toxic materials at the street surface, in urban runoff, and CSOs for more than 10 yr. This has resulted in a large data base that identified urban runoff as a principal source of toxic pollutants, e.g., New York Harbor receives metals from treatment plant effluents, combined sewer discharges, separate storm sewer discharges, and untreated wastewater (15). As seen in Table 3, urban runoff is the major contributor of heavy metals to the harbor.

Table 4 shows the total annual mass of selected constituents from a combined sewer and storm overflow point in Seattle (19). A high percentage of the heavy metals and toxic materials is associated with the suspended solids or particulates which may tend to concentrate in the sediments. This association is beneficial in terms of treatment since it is easier to separate pollutants attached to suspended solids.

Sediment samples were analyzed for metals, organic carbon, phosphorous, chlorinated hydrocarbons, and polychlorinated biphenyls (PCBs). As can be seen from Fig. 9, a composite index to assess wet-weather impacts was 16 times the minimum background control value. Also, pesticide levels in sediments

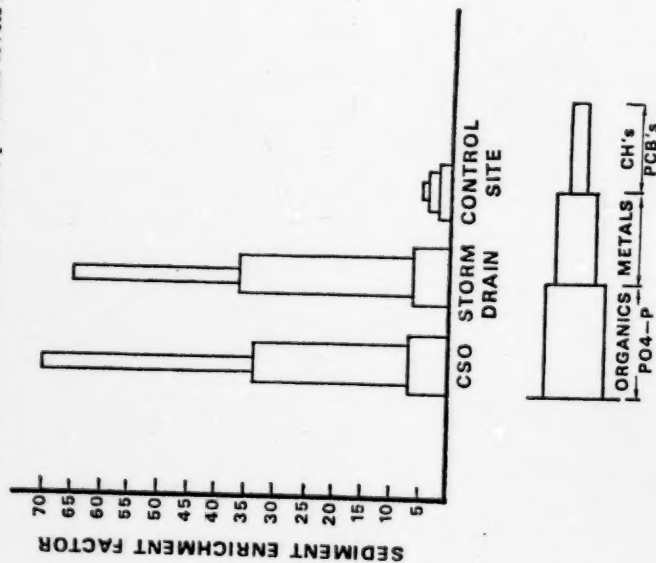


FIG. 9.—Illustration of Urban Sediment Enrichment: Lake Washington, Seattle, Washington

along the Seattle shoreline of Lake Washington were up to 37 times background concentrations. The measured pesticide content of the sediments was predominantly DDT and its degradation products. Since DDT is no longer used, this indicates a potential problem with the use of newer toxic chemicals, their transport, and long-term fate.

In the previously mentioned San Jose project (17), urban sediment compared to nonurban sediment from Coyote Creek contained, e.g., using peak values, higher concentrations of lead (up to 10 times greater)—400 mg/kg versus 40 mg/kg, arsenic (9 times greater)—13 mg/kg versus 1.5 mg/kg, BOD₅ (up to 4.4 times greater)—1,900 mg/kg versus 925 mg/kg, and ortho phosphates (up to 4 times greater)—6.7 mg/kg versus 1.8 mg/kg. These are exemplifications

(using peak values) of a general trend. Significantly greater concentrations of high molecular weight hydrocarbons and oxygenated compounds were also found in the urban samples.

Lead concentrations in urban samples of algae, crawfish, and cattails were two to three times greater than in nonurban samples, while zinc concentrations were about three times the nonurban concentrations. Bioaccumulation of lead and zinc in the organisms compared to water column concentrations was at least 100 times—500 times greater.

Petroleum enters urban runoff from many sources—motor vehicles being the most significant. It may be attributed to spills, leaks, and disposal of motor vehicle lubricants, antifreeze, and hydraulic fluid.

Petroleum hydrocarbons, particularly the polynuclear aromatics, have been shown to be carcinogenic and mutagenic. At New York City's Newton Creek treatment plant (15), 24,000 gal (90,840 l) of oil and grease, equivalent to a moderate spill (1) were bypassed during one four hour storm. The SCS Program's Jamaica Bay study (4) found that 50% of the hexane extractable material contributed to the bay is due to CSOs. It is clear that further investigation into receiving water impacts due to urban runoff warrants consideration.

A recently funded project (Tift, E., et al., Unpublished Report, United States Environmental Protection Agency Grant No. CR-806640) with Onondaga County involves screening urban runoff and CSO for bacterial mutagens and the assessment of the mutagenic/carcinogenic potential of the toxicants.

Recently, the SCS Program arranged with United States Environmental Protection Agency's Region II Surveillance and Analysis Division to analyze for priority pollutants in urban samples supplied from ongoing projects. Initial analyses show that a significant amount of priority pollutants are present in urban runoff. Fifty-nine of the 129 priority pollutants have been identified from analysis of 24 samples (15 liquid and nine sediment) obtained from nine urban areas. Concentrations were generally in micrograms per liter ($\mu\text{g/L}$) for the liquid samples and milligrams per kilogram (mg/kg) for the sediment. The 13 heavy metals were found in all the samples. Polynuclear aromatic hydrocarbons were the most frequently detected organics followed in order by phthalate esters, aromatic hydrocarbons, halogen derivatives of hydrocarbons, and phenols.

In FY'80, this effort will be supplemented with extramural assistance. In any case, in all appropriate projects, priority pollutant runs are taken to initially identify toxic substances for source identification and source control studies.

CONTROL METHODOLOGY BASED ON IMPACTS

The optimal goal of an urban stormwater pollution control study is to evaluate the relative impact of runoff and CSOs on the receiving waters and decide what control alternatives would be most cost effective in reducing wet-weather pollution. Impacts are often site specific and the extent of the problems will depend heavily on local conditions, such as rainfall quantities, point sources of pollution and their treatment, land use, and the sensitivity of the receiving water.

In an effort to catalog existing data, case studies of documented receiving water impacts are being reviewed in a project with the University of Florida (Heaney, J., and Huber, W., Unpublished Report, United States Environmental

Protection Agency Grant No. 805663). The project is expected to identify the types of impacts requiring further verification and the research needed to quantify receiving water stresses.

The concept of a simplified continuous receiving water quality model was developed in the nationwide evaluation of CSOs and urban stormwater discharges project (5) and refined into a user's manual during a subsequent project (12). This model, termed "Level III—Receiving," permits preliminary planning and screening of areawide wastewater treatment alternatives in terms of frequency and of water quality violations based on time and distance varying DO profiles. Fig. 10 represents a type of analysis (hypothetical example) facilitated by this model (3).

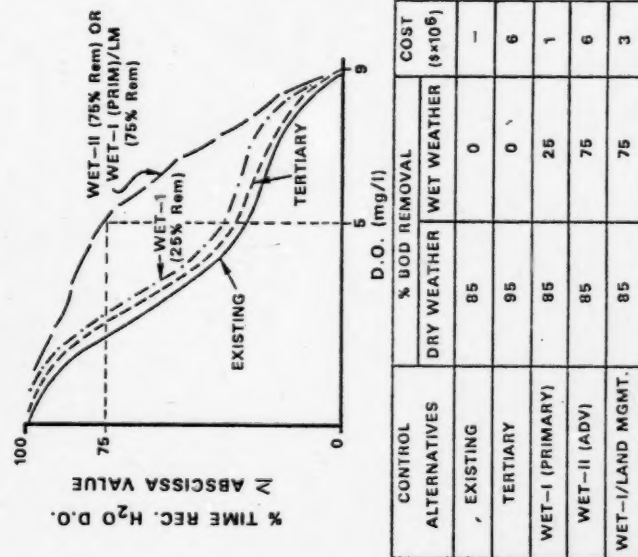


FIG. 10.—Hypothetical Example Solution Methodology

Using this analysis a truer cost-effectiveness comparison can be made based on the duration of the impact and associated abatement costs, e.g., if a 5 mg/l DO is desired in the receiving water 75% of the time, an advanced form of wet-weather treatment or primary wet-weather treatment integrated with land management is required. The latter is the most cost effective at \$3,000,000. This tool will aid in setting cost-effective standards as well as the selection of alternatives.

Also, a general methodology has been developed for evaluating the impact of CSOs on receiving waters and for determining the abatement costs for various water quality goals (14). It was developed from actual 201 facility planning experience in Onondaga Lake in Syracuse, N.Y. An important goal of studies

to determine the impact of waste discharges on a receiving water is to predict the waste loads that can be assimilated without violation of water quality standards so that a loading curve such as shown in Fig. 11 can be defined.

This figure shows the potential effect storm loads may have in violating a 5 mg/l DO standard after dry-weather treatment is upgraded. It further implies that CSO pollution loads should be abated next, since they are the easiest of the storm loads to control and capture.

The methodology outlines the interrelationships of various phases of a CSO study and develops procedures necessary to arrive at the costs to meet various water quality goals.

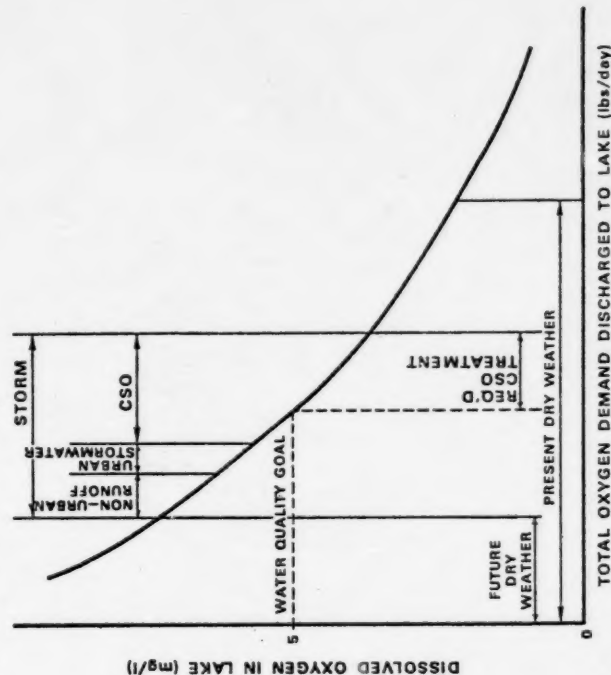


FIG. 11.—Typical Loading Curve Relating Pollutant Load to Water Quality Response

A project has been initiated with Manhattan College (Mancini, J., et al., Unpublished Report, United States Environmental Protection Agency Grant No. R-806828) to develop a methodology for defining criteria for wet-weather water quality standards. The methodology will provide assistance in determining the degree of treatment required for intermittent urban discharges. In recognition of an important gap in the aforementioned developed methodologies, the duration of water quality standards violations versus species survival will be taken into consideration. This may be difficult to accomplish since there is a significant lack of data in this area.

The research will include the definition and testing of a method for evaluating wet-weather water quality criteria considering both classical pollutants and toxics for different types of receiving waters. Load matrices will be developed for determining the load of a constituent as a function of urban area size and

the size and frequency of wet-weather events. These arrays will act as input to effects matrices.

Other factors influencing the effects matrices are the receiving water size and type and the organism/contaminant transformations. Thus, situations where water quality problems associated with discharges from urban runoff will be defined. An effort will be made to generalize the results on anticipated problem solutions to yield a national scale assessment of the magnitude of the problem.

This project will be coordinated with other ongoing receiving water impact studies both within and outside the SCS Program.

A user's manual/guidebook for wet-weather flow quality and quantity monitoring is currently being developed (Sonnen, M. et al., Unpublished Report, United States Environmental Protection Agency Grant No. R-806345). There are various reasons for entering into a wet-weather sampling and monitoring program and based on the desired objectives the philosophy of approach will vary. This manual will delineate methods to statistically satisfy various wet-weather sampling/monitoring needs/objectives. Also included are sections on best management practice (BMP) evaluation methodologies and receiving water impact methodologies to assure statistical reliability and transferability of data within these areas.

CONCLUSION AND RECOMMENDATIONS

Under certain conditions storm runoff can govern the quality of receiving waters regardless of the level of dry-weather flow treatment provided. Therefore, control of runoff pollution can be a viable alternative for maintaining receiving water quality standards.

The SCS Program has had only partial success in finding urban storm flow generated receiving water impacts employing the conventional DO parameter. The problem appears to be in the application of conventional dry-weather monitoring in unsteady-state flow regimes caused by storms. Based on a comparative analysis of wet versus dry-weather oxygen demanding substance loads, there remains a high potential for adverse impacts to occur in receiving waters. Further studies should be undertaken to resolve the anomaly between actual runoff loadings and observed receiving water impacts. The program has been more successful in sediment analysis than in water column analysis for DO depletions. Direct evidence has been obtained from the Milwaukee River project (13) of how a disturbed benthos depletes DO from the overlying waters. Studies have also shown that storm and CSO adversely affect sediment by toxics enrichment and resultant biological upsets. Since particulate matter in untreated storm and CSO is larger, heavier, and in significant quantities when compared to treated sanitary effluent, more needs to be known about the fate and transport of settleable and separable materials. Hydrodynamic solids separation and sediment transport routines must be added to receiving water models to take care of the neglected or presently omitted significant particulate and bed-load flow fields.

Urban runoff has been identified as a major source of toxic substances including heavy metals, which have been shown to concentrate in biological species and sediment, and petroleum hydrocarbons some of which are known carcinogens and mutagens. Very little is known about the long-term effects of these substances.

Further investigation into their receiving water impacts is required. Integration of various research program efforts and results are needed in this area to optimize benefits, avoid duplication, and minimize cost.

In the area of control methodology, a simplified continuous receiving water quality model has been developed for preliminary planning and screening of areawide wastewater treatment alternatives in terms of frequency of water quality violations. Also, a general methodology has been developed for evaluating the impact of CSOs on receiving waters and for determining the abatement costs for achieving various water quality goals. Still more work is needed on these methodologies.

Billions of dollars are being spent by the United States Environmental Protection Agency and others for water pollution cleanup. In order for governments to execute their functions in this area properly, ties between receiving water quality and impairment of both beneficial uses and water quality objectives by wet-weather flow pollution must be considered. Research and development must be fostered to back this need.

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